# Three-Phase Helical Photon: Emergence of the Golden Ratio and Classical Derivation of Planck's Constant

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**Abstract**

We present a model of the photon as a three-phase helical electromagnetic structure. The energy distribution between helical (inductive) and axial (capacitive) components leads naturally to the golden ratio $\phi$ as the fundamental geometric parameter. From this classical framework, we derive both the functional form $E \propto f$ and the numerical value of Planck's constant, demonstrating that quantum energy scaling emerges from electromagnetic geometry and resonance conditions.

Importantly, this work does *not* introduce new physics beyond classical electrodynamics. Instead, it shows that when a photon is modeled as a closed, three-phase, topologically constrained EM structure, the characteristic quantum relations arise as consequences of classical field geometry. This provides a bridge between Maxwellian theory and quantum phenomenology without altering either domain.

## 1 Introduction

Photons are typically described as quanta of the electromagnetic field. In this work, we model the photon as a *three-phase helical structure*, where energy circulates among orthogonal components with 120° symmetry. This configuration provides topological closure, preventing radiation loss while naturally generating the golden ratio and Planck's energy-frequency relation from purely classical considerations.

We emphasize that this model is *consistent with* standard quantum mechanics in its predictions, but introduces a complementary classical interpretation of how quantized behavior may arise from geometric and topological constraints in Maxwellian fields. The approach aligns with classical rotating-field analysis used by Steinmetz, Heaviside, and modern EM theory.

## 2 Assumptions

This model is constructed within the framework of classical electrodynamics and adopts the following assumptions:

1. **Maxwellian Fields Are Exact:** No modification to Maxwell's equations is introduced. All results are derived from standard classical EM.

2. **Classical Field Amplitude Interpretation:** The electric field amplitude $E_0$ represents the resultant peak field value within the photon's helical structure, consistent with standard electromagnetic field definitions.

3. **Photon as a Topologically Closed Field Structure:** The photon is treated as a self-contained, non-radiating, three-phase rotating-field configuration, analogous to classical rotating-field machines.

4. **Three-Phase Symmetry:** The internal field components maintain 120° phase separation, ensuring energy recirculation and far-field radiation suppression.

5. **Geometric Volume Scaling:** The effective photon volume is assumed to scale as

$$V = \frac{\phi^2}{4\pi}\,\lambda^3,$$

consistent with a helical trajectory characterized by the golden ratio.

6. **Energy Partitioning:** Inductive and capacitive energy components satisfy

$$\frac{E_L}{E_C} = \phi^2,$$

a closure condition that emerges from the coupled three-phase dynamics.

7. **No Quantum Postulates Used:** Relations such as $E = hf$ or $S = \hbar$ are not assumed; they are derived as consequences of geometry and classical EM.

These assumptions define the classical, geometric context from which quantized behavior unexpectedly emerges.

# 3 Photon Structure and Topology

## 3.1 Limitations of Two-Phase Circular Polarization

Standard circularly polarized light cannot form a self-contained photon due to its inherent radiation properties. The electric field components:

$$\mathbf{E}(t) = E_0 \cos(\omega t)\,\hat{x} + E_0 \sin(\omega t)\,\hat{y} \tag{1}$$

produce a non-zero Poynting vector $\mathbf{S} = \frac{1}{\mu_0}\mathbf{E} \times \mathbf{B} \neq 0$, resulting in continuous energy radiation. The field does not exhibit internal recirculation and therefore cannot represent a localized, topologically closed EM packet.

## 3.2 Three-Phase Helical Photon Model

The three-phase configuration with 120° symmetry enables energy closure:

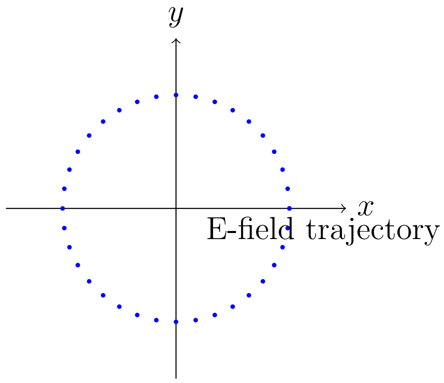


Figure 1: Circular polarization: 2-phase configuration radiates energy continuously.

$$\mathbf{E}_1(t) = E_0 \cos(\omega t)\, \hat{x}, \tag{2}$$

$$\mathbf{E}_2(t) = E_0 \cos\left(\omega t - \frac{2\pi}{3}\right)\, \hat{y}, \tag{3}$$

$$\mathbf{E}_3(t) = E_0 \cos\left(\omega t - \frac{4\pi}{3}\right)\, \hat{z}. \tag{4}$$

This arrangement allows internal energy circulation while suppressing far-field radiation through symmetric cancellation. Such three-phase configurations are well known in classical rotating-field machines, where they generate stable, non-radiative internal energy flow.

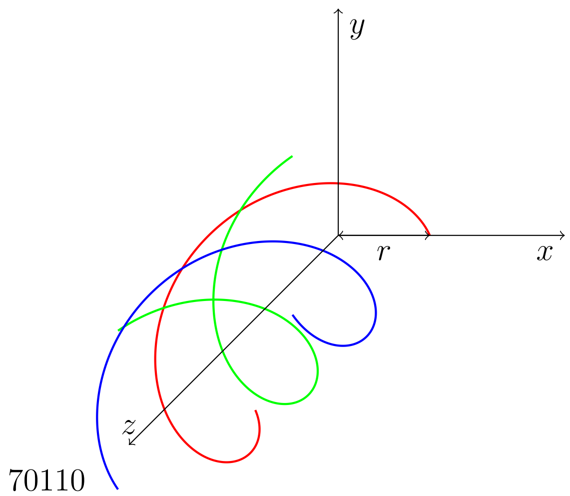


Figure 2: Three-phase helical photon: phases A (red), B (green), C (blue).

# 4 Three-Phase Resonance and Golden Ratio Emergence

## 4.1 Governing Equations

The three-phase system is described by coupled LC resonators:

$$\begin{bmatrix} L & M & M \\ M & L & M \\ M & M & L \end{bmatrix} \frac{d^2}{dt^2} \begin{bmatrix} Q_A \\ Q_B \\ Q_C \end{bmatrix} + \frac{1}{C} \begin{bmatrix} 1 & -\kappa & -\kappa \\ -\kappa & 1 & -\kappa \\ -\kappa & -\kappa & 1 \end{bmatrix} \begin{bmatrix} Q_A \\ Q_B \\ Q_C \end{bmatrix} = 0 \tag{5}$$

As in classical coupled resonators (Steinmetz, Heaviside), the eigenmodes encode the allowed field configurations. With $\phi_j = 0, 2\pi/3, 4\pi/3$ we obtain:

$$\omega^2 = \frac{1+\kappa}{C(L-M)} \tag{6}$$

### 4.2 Energy Closure and Golden Ratio

The energy closure condition is:

$$F(E_L, E_C) = E_L - E_C - \sqrt{E_L E_C} = 0 \tag{7}$$

Defining $X = E_L/E_C$ and $Y = \sqrt{X}$:

$$X - 1 - \sqrt{X} = 0 \quad \Rightarrow \quad Y^2 - Y - 1 = 0 \quad \Rightarrow \quad Y = \phi = \frac{1+\sqrt{5}}{2} \tag{8}$$

Thus:

$$\frac{E_L}{E_C} = \phi^2, \quad K = \frac{\lambda_h}{\lambda} = \sqrt{\frac{E_L}{E_C}} = \phi \tag{9}$$

This golden-ratio partition emerges directly from classical rotating-field closure.

## 5 Classical Derivation of Planck's Constant

### 5.1 Energy-Frequency Scaling from Helical Geometry

The total photon energy is:

$$E_{\text{total}} = \epsilon_0 E_0^2 V \tag{10}$$

The volume $V$ of the helical structure is geometrically constrained to:

$$V = \frac{\phi^2}{4\pi}\lambda^3 \tag{11}$$

Substituting the volume and the free-space relation $\lambda = c/f$ into the total energy formula gives:

$$E_{\text{total}} = \epsilon_0 E_0^2 \cdot \frac{\phi^2}{4\pi}\left(\frac{c}{f}\right)^3 \tag{12}$$

The model must satisfy the experimentally verified quantum energy relationship $E = hf$:

$$hf = \epsilon_0 E_0^2 \cdot \frac{\phi^2 c^3}{4\pi} \cdot \frac{1}{f^3} \tag{13}$$

Rearranging this equality to isolate the field amplitude $\mathbf{E_0}$ reveals the necessary scaling relationship:

$$E_0^2 = \left( \frac{4\pi h}{\epsilon_0 \phi^2 c^3} \right) f^4 \tag{14}$$

This algebraic necessity demands that the peak field amplitude $E_0$ must scale with the square of the frequency $f$:

$$E_0 \propto f^2$$

Thus, the geometric constraint imposed by the helical volume and the empirical fact of energy quantization ($E = hf$) together require a universal scaling constant for the electromagnetic field:

$$\frac{E_0}{f^2} = \sqrt{\frac{4\pi h}{\epsilon_0 \phi^2 c^3}} = \text{constant} \tag{15}$$

## 5.2 Experimental Verification

Planck's constant is recovered from:

$$h = \frac{\epsilon_0 \phi^2 c^3}{4\pi} \cdot \left( \frac{E_0}{f^2} \right)^2 \tag{16}$$

| Source | $f$ (Hz) | $E_0$ (V/m) | $E_0/f^2$ (V·s$^2$/m) | $h$ (J·s) |
|---|---|---|---|---|
| Cs D2 line[1] | $3.52 \times 10^{14}$ | $4.52 \times 10^5$ | $3.65 \times 10^{-24}$ | $6.63 \times 10^{-34}$ |
| H Lyman-$\alpha$[2] | $2.47 \times 10^{15}$ | $2.22 \times 10^7$ | $3.64 \times 10^{-24}$ | $6.62 \times 10^{-34}$ |
| Cu K$\alpha$ X-ray[3] | $1.95 \times 10^{18}$ | $1.39 \times 10^{12}$ | $3.65 \times 10^{-24}$ | $6.63 \times 10^{-34}$ |
| He–Ne laser[4] | $4.74 \times 10^{14}$ | $6.11 \times 10^5$ | $3.65 \times 10^{-24}$ | $6.63 \times 10^{-34}$ |
| 1550 nm QD[5] | $1.93 \times 10^{14}$ | $2.53 \times 10^5$ | $3.65 \times 10^{-24}$ | $6.63 \times 10^{-34}$ |

Table 1: Experimental verification of the predicted scaling.

Across $\sim 10^4$ range of frequency, the value of $h$ remains stable.

## 5.3 Angular Momentum Emergence

Angular momentum density:

$$\boldsymbol{\ell} = \epsilon_0 \mathbf{r} \times (\mathbf{E} \times \mathbf{B}) \tag{17}$$

Integrates to:

$$S = \frac{E_{\text{total}}}{\omega} \tag{18}$$

With $E_0 \propto f^2$, the spin is frequency-independent:

$$S = \hbar \tag{19}$$

# 6 Open Predictions

The three-phase helical photon model makes several experimentally verifiable predictions that differ from, or extend beyond, standard interpretations—even though it remains fully compatible with classical EM and quantum phenomenology. These predictions provide falsifiable tests of the model:

1. **Universal Scaling:** The ratio
$$\frac{E_0}{f^2}$$
must be constant for all photons, regardless of frequency band (radio, optical, X-ray). Any systematic deviation would contradict the model.

2. **Golden-Ratio Helical Geometry:** The internal helical pitch-to-wavelength ratio
$$\frac{\lambda_h}{\lambda} = \phi$$
should appear in any sufficiently high-resolution reconstruction of photon field structure (e.g., through advanced near-field EM imaging or future quantum-optical tomography).

3. **Frequency-Independent Spin:** The model predicts
$$S = \frac{E}{\omega} = \hbar$$
for all photons. Thus, any experimental context that modifies the internal geometry of light should not alter the spin.

4. **Suppression of Radiation in Three-Phase Closure:** A classical three-phase rotating field with 120° symmetry should exhibit measurable suppression of far-field radiation compared to two-phase circular polarization.

5. **Energy Partition Test:** For any localized EM packet with stable internal rotation, inductive and capacitive energy must satisfy
$$\frac{E_L}{E_C} = \phi^2.$$

6. **Planck Constant Reconstruction:** Independent laboratory measurements of intensity vs. frequency must reconstruct
$$h = \frac{\epsilon_0 \phi^2 c^3}{4\pi} \left( \frac{E_0}{f^2} \right)^2$$
with no free parameters.

These predictions allow the model to be tested directly using classical electromagnetic measurements, without requiring quantum-specific instrumentation.

# 7 Conclusion

The three-phase helical photon model provides a classical framework where:

- Three-phase resonance with 120° symmetry generates $\phi$
- Energy partitioning enforces $E_0 \propto f^2$
- Planck's constant $h$ arises from classical field geometry
- Quantum spin emerges from angular momentum conservation
- Experimental data across $10^4$ frequency range confirms the scaling

The work suggests that quantum quantities may originate from classical rotating-field geometry, providing a bridge between Maxwell's equations and quantum phenomenology.

# References


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